

MODELING OF VOLATILES LOSS DURING LUNAR RESOURCE PROSPECTOR MISSION SMAPLE ACQUISITION

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Introduction: Here we report on our current effort to model the volatiles transport in lunar regolith. This research had been carried out in the context of the NASA's Resource Prospector (RP) [1]. The main objective of this NASA mission to the high latitudes and permanently shadowed regions of the Moon is the identification and extraction of volatile species in the top meter of the lunar regolith layer. Vacuum experiments have taken place at NASA's Glenn Research Center with one aim being to quantify volatiles loss during the RP drilling/sample acquisition phase and sample delivery to the crucibles steps. Outputs of these experiments germane to the calculations include:

- i) Temperature measurements within and on the surface of the lunar simulant;
- ii) Temperature measurements at the tip of the drill;
- iii) Empirical measurements of the post-test water distribution within the lunar simulant.

In May 2016, two different soil tubes (ST1 and ST2) were prepared with lunar highlands simulant (NULTH-3M) containing ~5 wt.% water. The two STs were placed in the Glenn vacuum chamber on two different dates. Once each tube was in the vacuum chamber, a thermal shroud was used to surround all components, the chamber was sealed and evacuated for ~48 hours. During evacuation liquid nitrogen flowed through coils wrapping the STs to cool the soils. The thermal shroud was maintained at 223K and 93K for ST1 and ST2, respectively. Once all the operations ended, the vacuum chamber was backfilled with N2 gas, returned to room pressure, opened and soil samples collected at increasing depths to measure the vertical water distribution within each ST.

We have been carrying out numerical modeling to understand the physics underpinning these experiments. Given the measured temperature field and the low volatile density our modeling employs Knudsen's law describing sublimation of volatile molecules at the grain surface [2]. We also mimic the soil porosity by randomly allocating 75 micron particles within the simulation volume. To model the molecular diffusion of volatiles we have implemented a 3-D numerical code that tracks macro-particles (each macro-particle represents a large number of water molecules) within the computational volume. At each instant, we compute a time-step that takes into account the relevant

local time scale. Knudsen's law includes a residence time, which depends strongly on temperature [2]:

$$\tau_K \propto \exp\left[-\frac{Q}{K_B T}\right] \times \sqrt{T}, \quad (1)$$

where K_B and Q and T are the Boltzmann's constant and sublimation enthalpy, and temperature in Kelvin respectively. As the temperature field in the STs is not uniform throughout the simulated volume and changes during the duration of the experiment, a time step, δt , at a given instant, t , as the largest of the $\tau_K(r, t)$ with-

in the simulated volume, where r and t denote position and time, respectively. The initial conditions of each numerical model is 5 wt.% water ice concentration. This corresponds to ~3000 water ice monolayers on the surface of each grain. At each time step, the number of particles leaving is proportional to the number of particles present at the grain surface with a "half-time" given by the local residence time. The fraction of molecules going in any direction is drawn using a Monte Carlo procedure in assuming an exponential distribution with a mean value λ . A condition is imposed that when a grain has less than fifty monolayers on its surface no molecules are allowed to leave. Here we report on the sensitivity of the results on two parameters applied to ST1 and ST2. These parameters are:

- i) Fraction of monolayers on the grain surface that leave at each time step. This is parameterized via λ (the mean number of monolayers leaving);
- ii) The mean density of water molecules (ρ_0) at the free surface of the ST.

Conclusions: When compared to the empirically determined vertical water distributions, the current model shows a better agreement than previous versions [3].

References: [1] D. R. Andrews, et al. (2014) *Introducing the Resource Prospector (RP) Mission* American Institute of Aeronautics and Astronautics; [2] F. Reif (1965) *Fundamentals of Statistical and Thermal Physics* Waveland Press; [3] L. A. Teodoro (2016) Molecular Diffusion of Volatiles in Lunar Regolith during the Resource Prospector Mission Sample Acquisition, AGU 2016, abstract id.P41A-2067